

sTGC | Interlock Design

Team:

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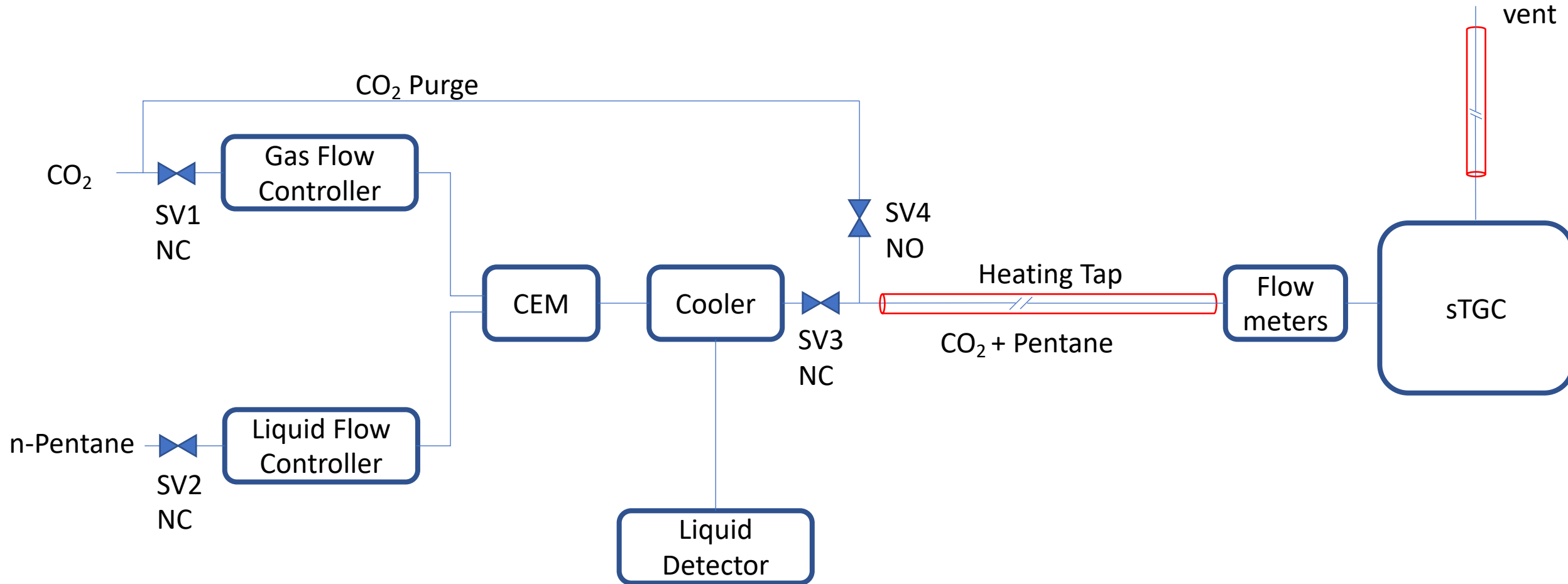
Mike Capotosto

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And great help from Robert Benkov, Automation Specialist, Turtle & Hughes

Design

Simplified sTGC Gas Flow Diagram



SV – Solenoid valves
NC – Normally closed
NO – Normally open

Some Facts

- Valves are chosen such that in case of loss of power, system will be in automatic purge mode
- Purge mode
 - Close SV 1,2,3 and Open SV4
 - Pure CO₂ flow
 - Gas mixing system will be isolated
- Latch the status after safety incident is cleared/fixed
 - The valves will continued to be in the purge mode
 - HV to the sTGC will be 0V
 - Clearing the alarm will not resume to normal operation, user needs to start the system
- Sensors, actuators and all the interlock hardware are chosen to have 24 VDC operating voltage

Alarm Groups

Alarm 1

Safety Concerns	Responses
Pentane leak in <ul style="list-style-type: none">• Gas cabinet• Flow meters• sTGC chambers• Sniffer malfunction w/ 15 min delay	<ul style="list-style-type: none">• Put the system in purge mode• Turn off HV (~2900 V) to the sTGC
Heat/Fire in <ul style="list-style-type: none">• Gas cabinet• Electronics rack• sTGC chambers-1• sTGC chambers-2	

Alarm 2

Safety Concerns	Responses
<ul style="list-style-type: none">• Supply line heat tape – Out of range• Vent line heat tape – Out of range	Initial 30 minutes <ul style="list-style-type: none">• Audible and visible alarm
	After 30 minutes <ul style="list-style-type: none">• Purge mode and HV to sTGC OFF

Alarm 3

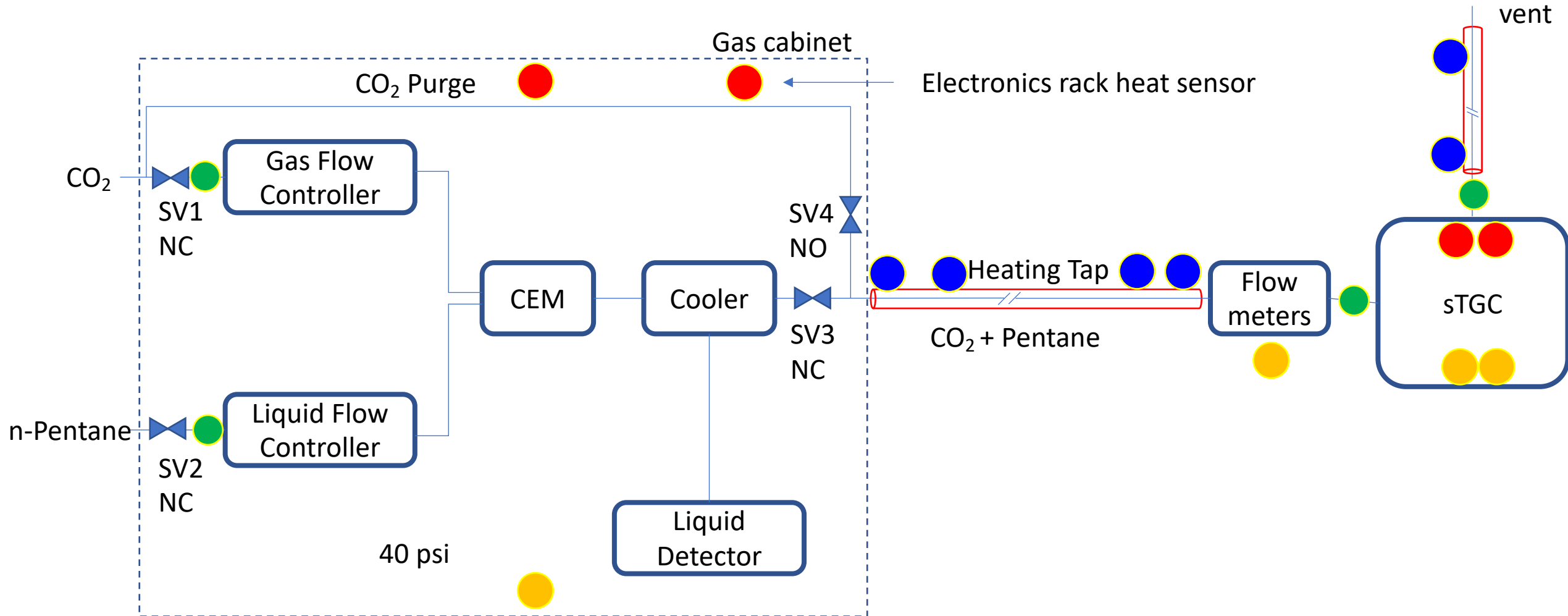
Safety Concerns	Responses
Liquid pentane present after mixing - LOW	Audible and visible alarm
Liquid pentane present after mixing - HIGH	Purge Mode and HV to sTGC OFF

State Table – For the interlock testing team

Status During Interlock	sTGC Purge	sTGC HV off	Audible & Visible Alarm
Normal status		(on)	
Interlocks			
Fire/Heat Detection	X	X	X
Heat in gas cabinet	X	X	X
Heat in electronic cabinet	X	X	X
Heat near sTGC chambers 1	X	X	X
Heat near sTGC chambers 2	X	X	X
Flammable Gas Detection			
15% of LEL in pentane sniffer - Gas cabinet	X	X	X
15% of LEL in pentane sniffer - Flow meters	X	X	X
15% of LEL in pentane sniffer - sTGC chambers 1	X	X	X
15% of LEL in pentane sniffer - sTGC chambers 2	X	X	X
Pentane sniffer malfunction w/15 min delay	X	X	X
Gas mixing and Delivery			
Liquid pentane present after mixing - LOW			X
Liquid pentane present after mixing - HIGH	X	X	X
Supply line heat tap -LOW/HIGH first 30 min			X
Supply line heat tap -LOW/HIGH after 30 min	X	X	X
Vent line heat tap -LOW/HIGH first 30 min			X
Vent line heat tap -LOW/HIGH after 30 min	X	X	X
Miscellaneous			
PLC communication error w/ 15 min delay	X	X	X
STAR TPC interlock	N/A		
STAR global interlock			

Sensors & Actuators

Location of the safety sensors

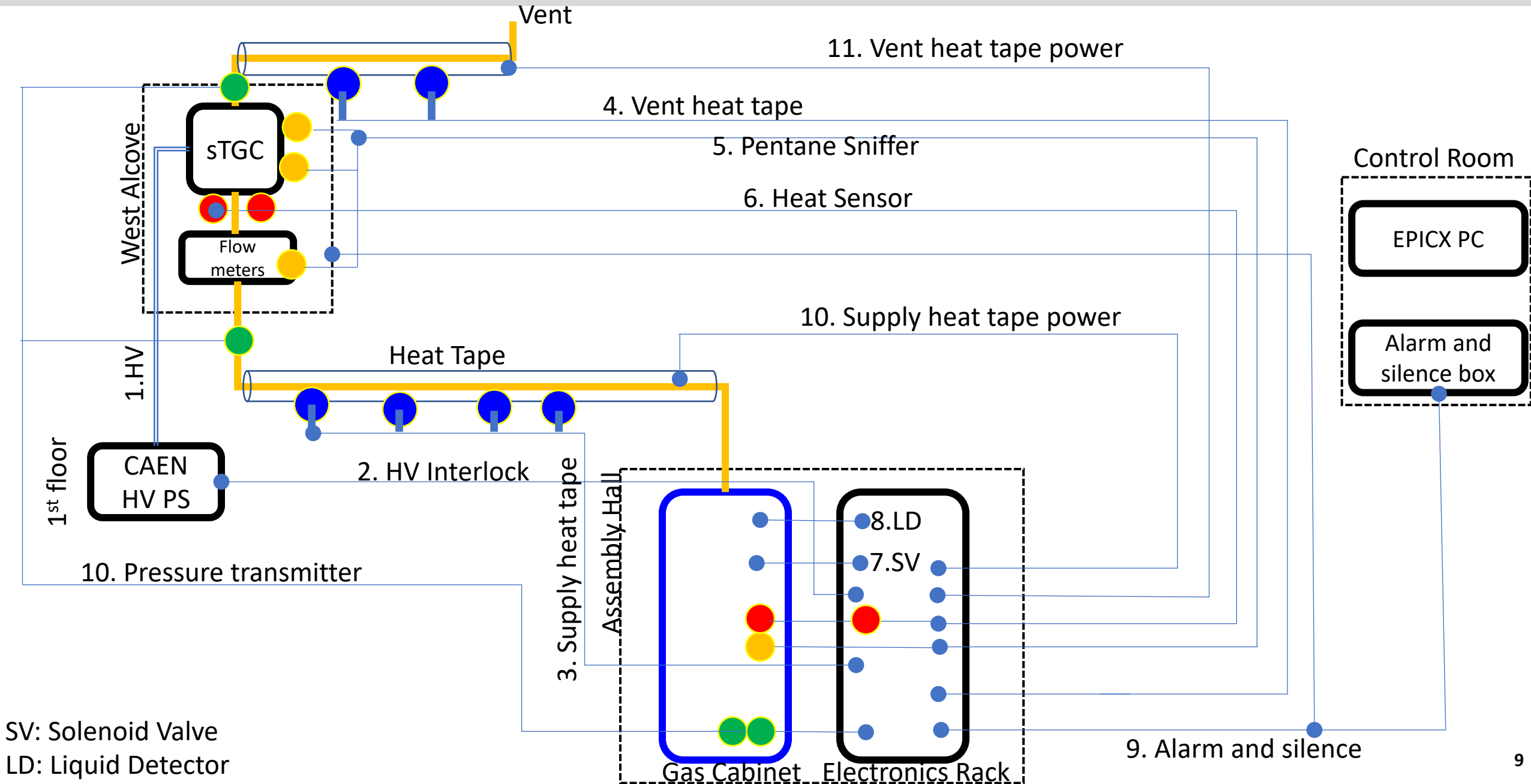


SV – Solenoid valves
NC – Normally closed
NO – Normally open

Yellow circle: Pentane Sniffer
Red circle: Heat sensor

Blue circle: Thermocouple
Green circle: Pressure transmitter

Wiring Schematic Diagram



Wiring Schematic Diagram					
Total: Coax = 150”, 2-wire = xxx”, 3-wire = yyy”, 4-wire = zzz”					
No	Function	No. of Sensors	No. wires/sensor	Length (ft)	Comments
1	HV cable from CAEN to sTGC	2 modules			Two cables in place from TOF CAEN to sTGC, good for Run 20 only
2	CAEN HV to PLC	-	Coax cable	150	+5 VDC signal
3	Supply heat tape Thermocouple to control module Control module to PLC	4 8 relays	2	10	Manufacturer provided Need to confirm with manufacture
4	Return heat tape Thermocouple to control module Control module to PLC	- 2 4 relay	2	10	Manufacturer provided Need to confirm with manufacture
5	Pentane sniffer sniffers to IR sniffer to gas cabinet sniffer control module to PLC	3 1 5 relays	3 3 2	150 10 10	With 18 AWG wire, can run up to 2500” from controller to sniffer head
6	Heat sensor Gas cabinet to PLC Electronics rack to PLC IR to PLC	1 1 2	2 2 2	10 6 150	Heat sensor built in relay 2.0 Amps max at 24 VDC
7	Solenoid valves to PLC	4 valves	3	10	24 VDC, 11.6 watts
8	Liquid detector to PLC	1	2	10	4...20 mA, 24 VDC
9	Alarm and silence Control room Gas cabinet IR	Warning light to IR Warning light to gas cabinet Siren to IR Siren to gas cabinet Buzzer to CR Amber indicator light to CR Push switch in gas cabinet Push switch in CR	2 2 2 2 2 2 2 2	100 10 150 10 100 100 10 100	
10	Pressure transmitter to PLC	After SV1 After SV2 Before sTGC After sTGC	4 4 4 4	6 6 150 150	4...20 mA, 24 VDC

Summary of alarms & Inputs to the PLC

	Sensor	Location	Alarm condition	Sensor communication protocol	PLC input port	Comments
1	Pentane Sniffer-1	Gas cabinet	> 1.5% of LEL	Relay		
2	Pentane Sniffer-2	Flow meters	> 1.5% of LEL	Relay		
3	Pentane Sniffer-3	Near sTGC	> 1.5% of LEL	Relay		
4	Pentane Sniffer-4	Near sTGC	> 1.5% of LEL	Relay		
5	Heat Sensor-1	Gas cabinet	> 190 ⁰ F	Relay		
6	Heat Sensor-4	Electronics cabinet	> 190 ⁰ F	Relay		
7	Heat Sensor-2	Near sTGC	> 190 ⁰ F	Relay		
8	Heat Sensor-3	Near sTGC	> 190 ⁰ F	Relay		
9	Temp of supply heat tape - High	Supply line	> 25 ⁰ C	Relay		
10	Temp of supply heat tape - Low	Supply line	<22 ⁰ C	Relay		
11	Temp of return heat tape - High	Return line	>40 ⁰ C	Relay		
12	Temp of return heat tape - Low	Return line	<22 ⁰ C	Relay		
13	Liquid detection Alarm LOW	Gas cabinet	Liquid present	4...20 mA		
14	Liquid detection Alarm HIGH	Gas cabinet	Liquid present	4...20 mA		
	PLC malfunction	-				
	Pentane sniffer malfunction	-	Relay get active	Relay		
	Silence siren	-	-	Push button		Two sirens are in series

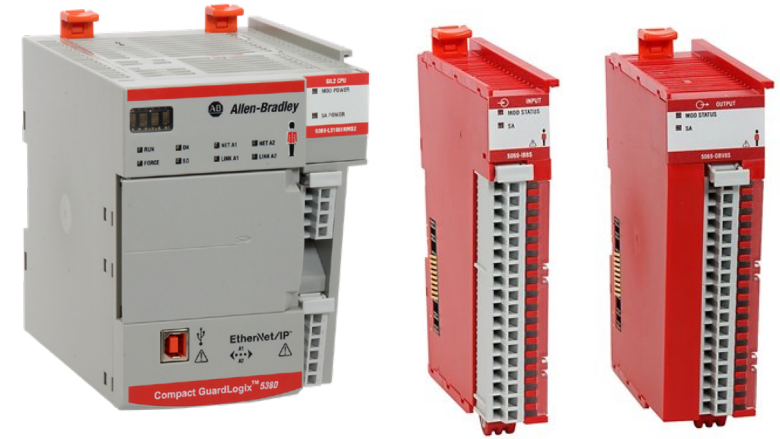
Output from the PLC

	Actuator	PLC output port	Comments
1	SV1		+24 VDC to open
2	SV2		+24 VDC to open
3	SV3		+24 VDC to open
4	SV4		+24 VDC to close
5	CAEN HV interlock		5V through relay
6	Alarm - sound		Two silence buttons, one in control room other is in gas cabinet
7	Alarm - Light		Three lights: Gas cabinet Control room At west platform

Hardware Selection

Interlock – Hardware

- Compact GuardLogix 5380
 - Safety PLC
 - SIL2/PLd certification
- Safety input module - 5069-IB8S
 - 8...32V DC 8-point, safety sinking input module
- Analog input - 5069-IF8
 - Pressure Transmitters & Liquid level sensor
- Safety output module - 5069-OBV8S
 - For solenoid valves and HV
- Standard output module - 5069-OX4I
 - For alarms and sirens
- HMI (Human Machine Interface)- PanelView 5310, 9"
- Needs to be finalized after ESC & SME review
 - Lead time can be two weeks



Solenoid Valves

- ASCO Class 1 Div 1 explosion proof valves
- Viton elastomers compatible with pentane/CO2
- 24 VDC, 11.6 Watts
- Chosen such that in case of power dip, valves put the system in purge mode

EF8262H208V 24DC

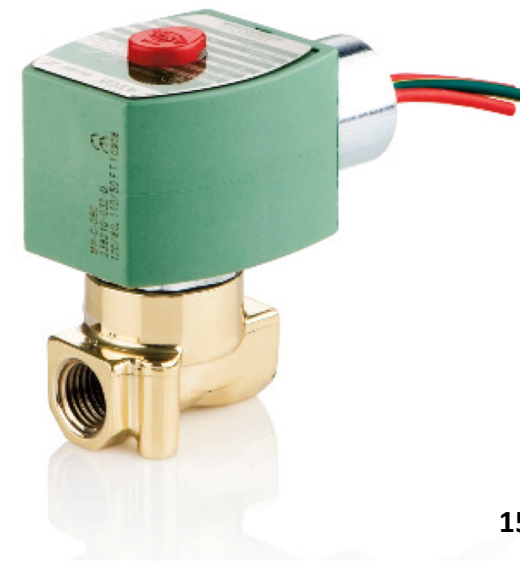
<https://www.asco.com/ASCO%20Asset%20Library/asco-series-262-263-general-service-catalog.pdf>

EF8210G094V 24DC

<https://www.asco.com/ASCO%20Asset%20Library/asco-series-210-general-service-catalog.pdf>

EF8210G034V 24DC

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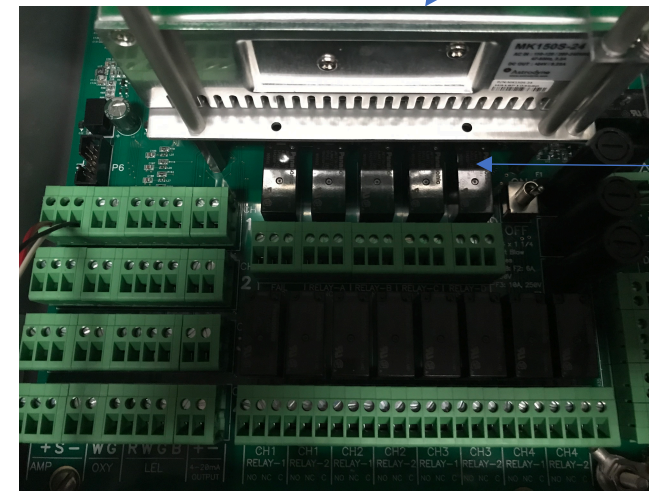


Pentane Sniffer

- RKI Instruments (previously used in STAR)
 - Beacon 410A, four channel controller
 - S2 Series LEL hydrocarbon sensor (catalytic) / transmitter with explosion proof j-box, UL
- Sensor is calibrated for Hexane (15% of LEL Hexane in Air)
 - response for factor for pentane and hexane is 1:1 and will work with this system
 - LEL of nPentane 1.4% by volume
 - LEL of Hexane 1.1% by volume
- Class 1, Division 1



Control unit and sniffer head



Malfunction and alarm relays
SPDT 10A @ 115 VAC

Heat Detector

- For detection of fire in the
 - Gas cabinet
 - Electronics rack
 - Near sTGC planes
- Pre set at 190⁰ F
- Detects surrounding air temperature
- Relay close on contact
 - Resistive electrical rating 2.0 Amps max at 24 VDC



Fenwal detect a fire unite
model number 12-X27121-020-001

Liquid Detector

- When the proper ratio of n-Pentane(liquid) and CO₂ is mixed at 17°C no pentane liquid should present and gas ratio should be n-Pentane:CO₂ = 45:55%
- This device is used to identify un-mixed pentane so the pentane liquid flow can be controlled
- VEGAFLEX 81: vibrating sensor detects liquid presence
- Output: 4 ... 20 mA/HART - two-wire



Heat Tape

- Heat tape is wrapped around supply and vent line to prevent pentane being liquifying
- Supply line is read via two thermocouples (with two spare) and vent line is read via single thermocouple (one spare)
- Supply line 22 – 25°C
- Vent line is 22 – 40°C
- Relay and sound for each thermocouple out of limit



Pressure Transmitters

- Not part of Interlock, only for monitoring
- Pressure relief valve are used for the pressure safety
- Measure the supply pressure of both CO2 duo and CO2 for n-pentane pump (~30 psi)
- Measures the input and output pressure of sTGC chambers (~2 mbar)
- 4-20 mA output at 24 VDC



Low pressure: 616KD-03

<https://www.dwyer-inst.com/Product/Pressure/DifferentialPressure/Transmitters/Series616KD#specs>

High pressure: 626-09-CB-P1-E5-S1

<https://www.dwyer-inst.com/Product/Pressure/SinglePressure/Transmitters/Series626-628?Query=626-09-CB-P1-E5-S1>

Status

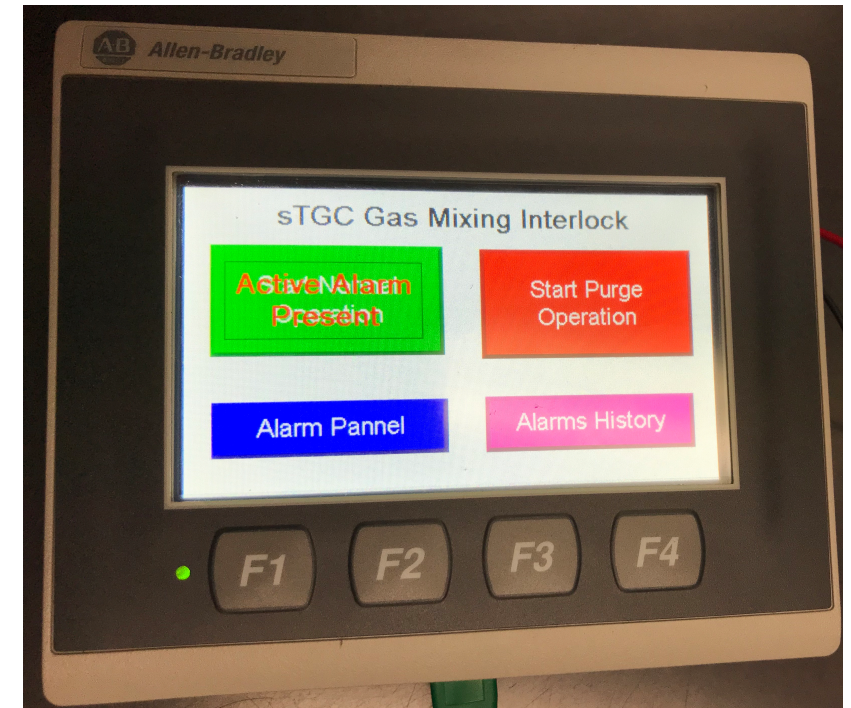
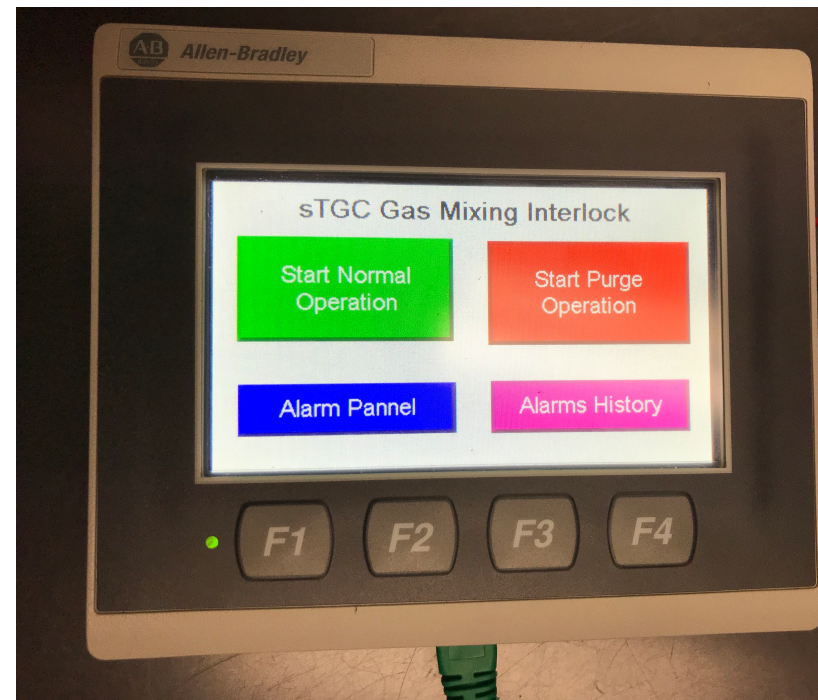
- Got a training PLC in hand, have good knowledge in
 - operation of PLC
 - ladder diagram
 - alarm logic
 - GUIs
- Later found this is not a safety PLC
- New safety PLC & components are selected, waiting for approval from ESC and SME safety groups

Backup

Design with Micro850 PLC (training kit)



- This is the first version, but in good shape
- There are some tweaks need to be done after hearing back from liquid detector and heat tape manufactures
- This is 4" display, will be replaced with 7" or 10" display
- Any comments?
- Do we need a bypass option?





Electronics Rack

- Items so far
 - PLC –
 - 24 VDC power supplies
 - HMI-9”
 - Switch box
 - Laptop/PC
 - Relay line
 - Cable connectors
 - Sniffer control module